POLARIMETRIC REMOTE SENSING OF CIRRUS CLOUDS

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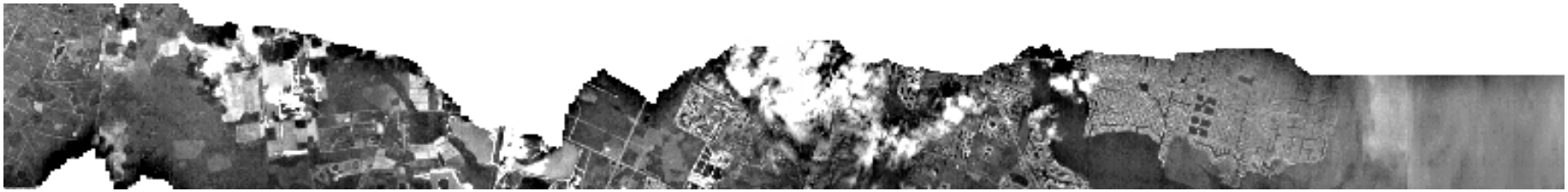
RSP Data Processing Summary

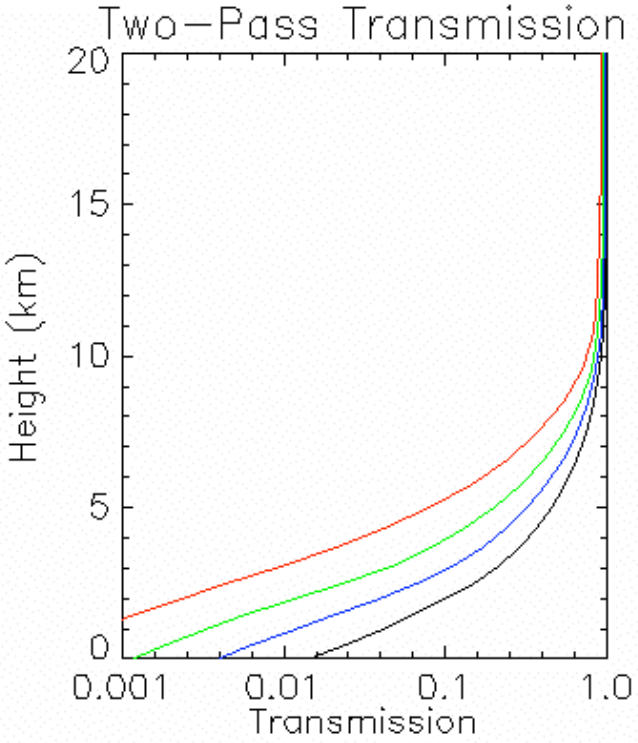
- All data has been processed and preliminary raw binary form of all data and quick looks is available at ftp://crystal-face.giss.nasa.gov.
- Radiometric calibration has been revised and an updated data set with merged GPS and tagged imagery will be released after the science team meeting.
- SWIR sensitivity reduced by 10% over the coarse of IHOP and CRYSTAL-FACE.
- VNIR sensitivity reduced by less than 5% over same period.
- Polarimetric calibration stable to better than 0.5% over both IHOP and CRYSTAL-FACE.

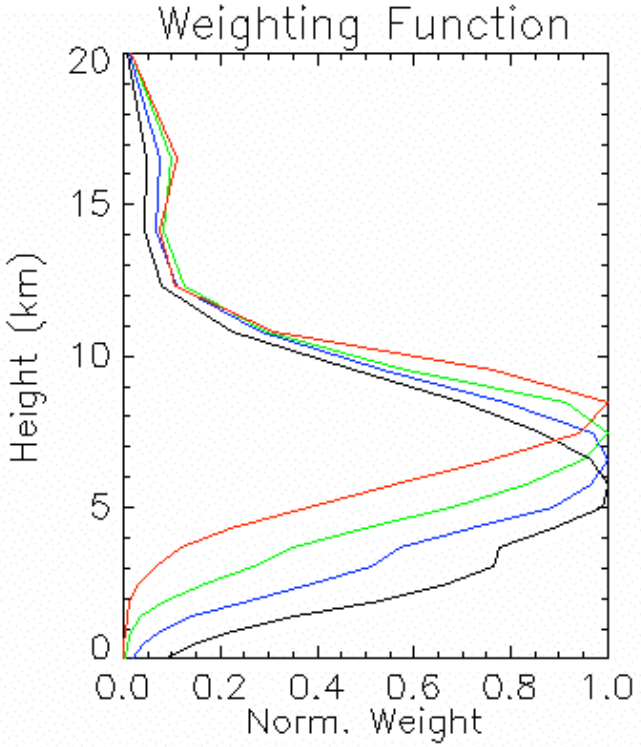
- There is a temperature dependence of absolute transmission of the telescopes that measure the Stokes parameter U at 470, 670 and 960 nm, although the relative Stokes parameter U/I appears to be unaffected.
- We will attempt to correct this temperature dependence in the revised data, but will note the problem in the data description.
- Main problem in synthesizing multi-looks of same point is stability of Proteus and absence of INS data. Some INS data has been made available by the Proteus crew, but is sporadic because they were debugging a new system.
- Lesson learned: we need and should have brought our own INS for use on Proteus.



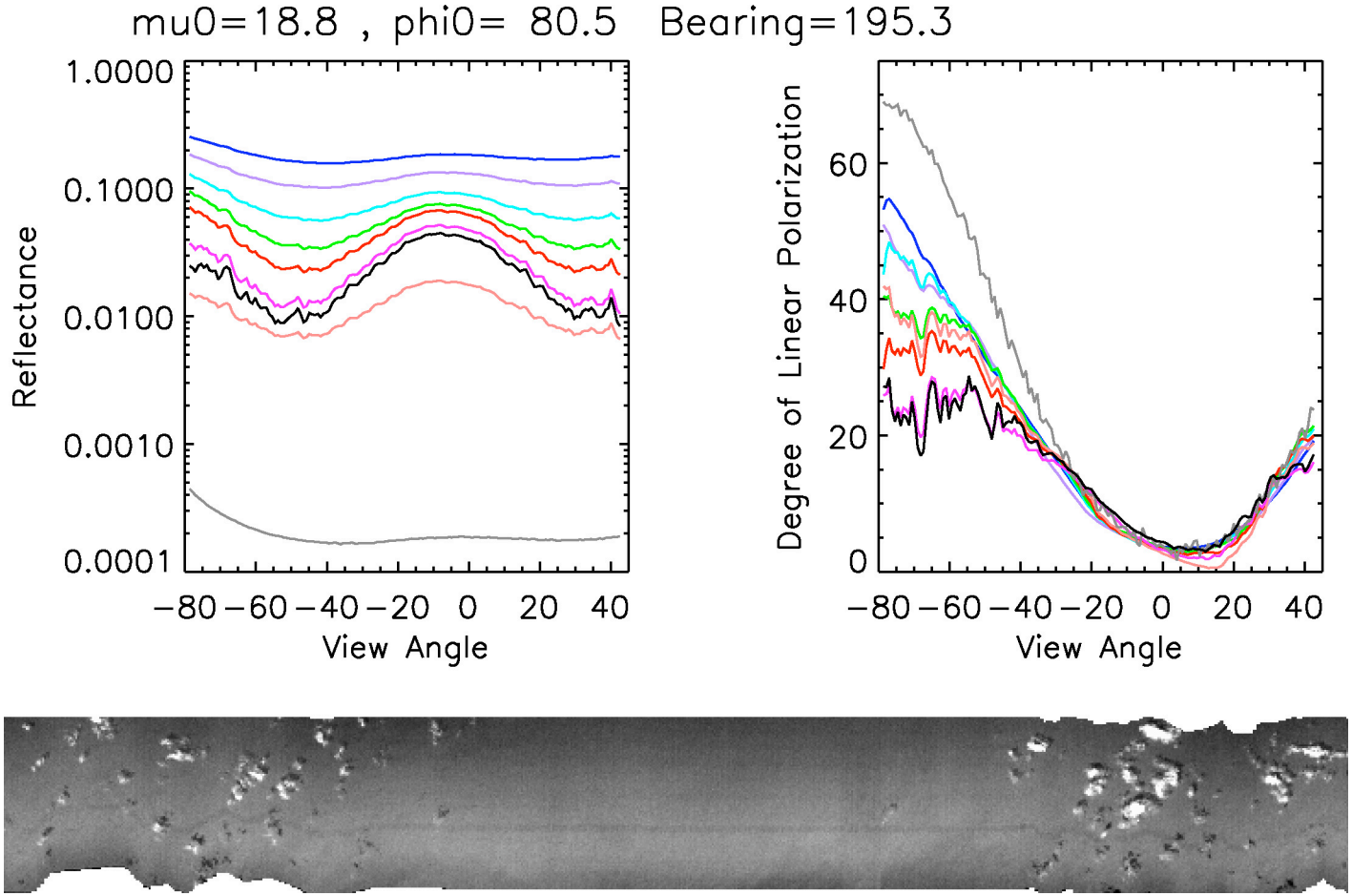
Thin Cirrus

- Primary channel for analyzing thin cirrus is the spectral band at 1880 nm that is in strong water vapor absorption.



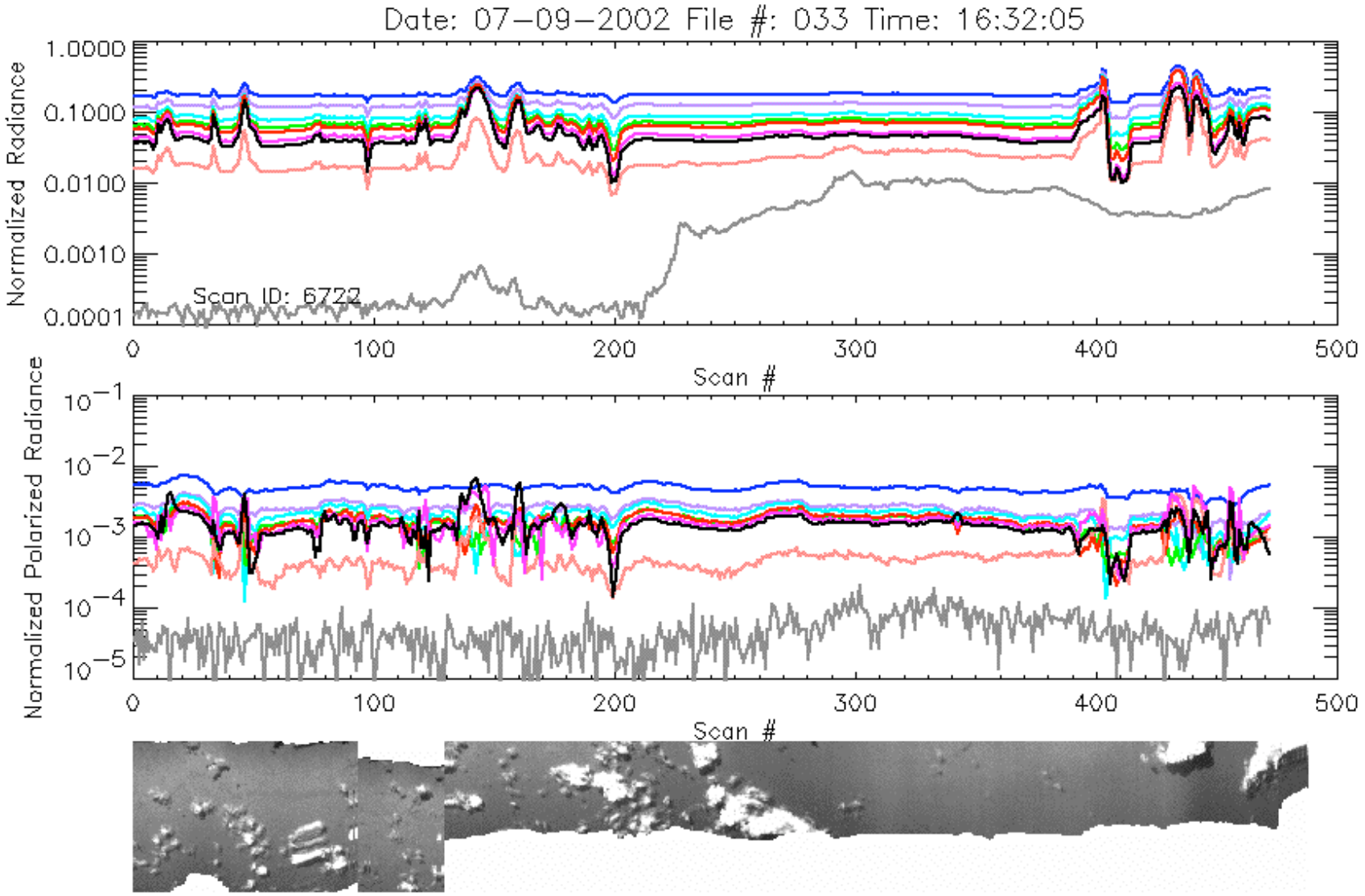


- What does clear sky look like in this band?
  - Throughout CRYSTAL-FACE the atmosphere was wet enough that the surface was never visible in this band. So surface and low level clouds have no effect on the identification of clear sky and high level cirrus cloud
  - This figure show an example of a case where the upper troposphere is clear of cloud.

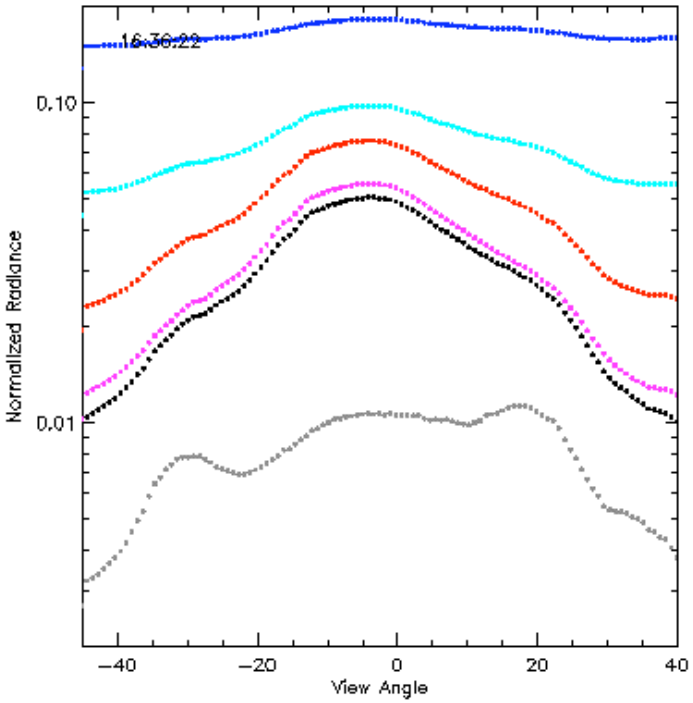


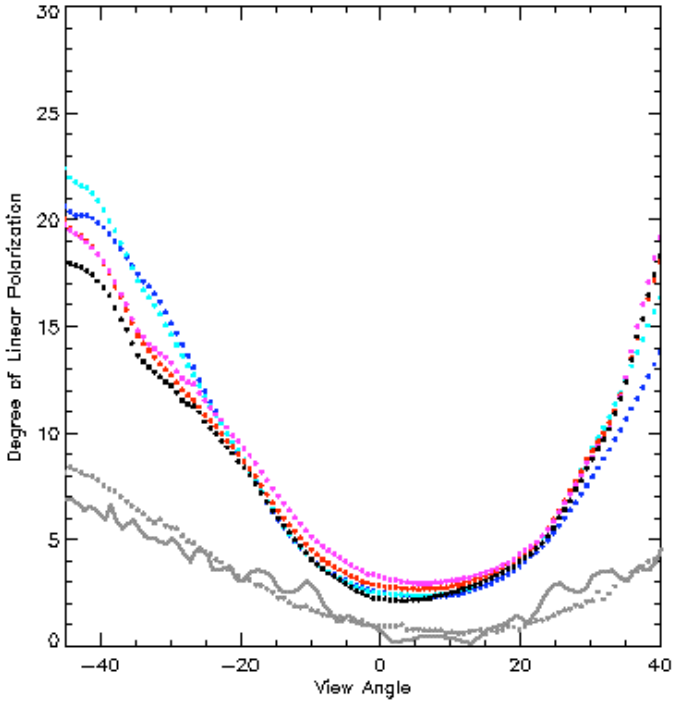
- In this figure the data has been aggregated at the tropopause level, averaged and is not cloud screened for boundary layer cumulus.
- The spectral bands are 410, 470, 555, 670, 865, 960, 1590, 1880 and 2250 nm shown in blue, mauve, turquoise, green, red, orange, purple, grey and black.
- The 1880 nm band (grey) has a reflectance of 0.0002 which would be commensurate with the presence of an upper tropospheric aerosol layer with an optical depth of less than 0.001 near the tropopause.
- To quantify the magnitude of the aerosol optical depth requires both back scatter profile information (CPL on ER-2) and water vapor profile information (NAST-I on Proteus).
- It is however clear from the polarization signal that the upper troposphere at this location is dominated by small (relative to 1880 nm) aerosols because the maximum polarization is near 70%.
- Any cirrus contamination reduces this polarization dramatically.

- Shortly after a thin cirrus layer appeared.



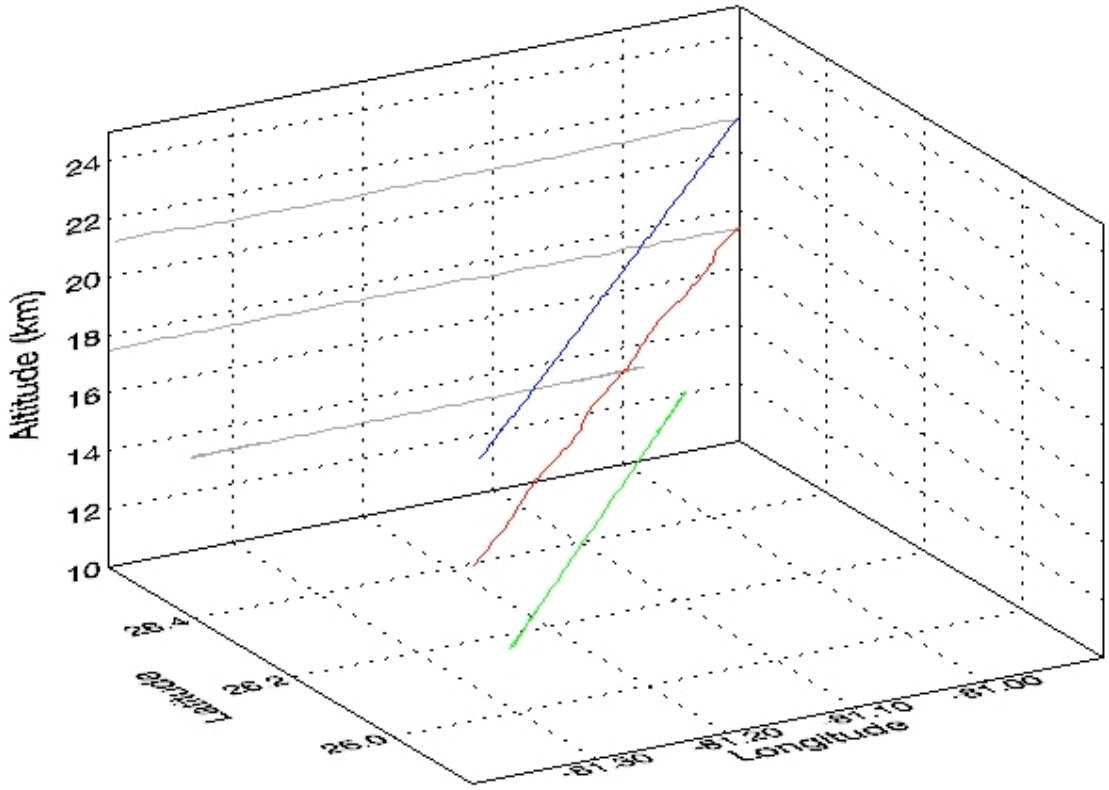
- Synthesizing a multi-angle view (at the tropopause level).
  - The polarization is dramatically reduced, and in this case the radiance increased by two orders of magnitude.
  - The radiance does not always increase by this much when a cirrus layer is present if it is thin, or well below the tropopause (screened by water vapor).
  - The polarization is always dramatically reduced though and for thin cirrus we have never seen any indication of the presence of pristine crystals.
  - The solid grey line below is a fit of a 20μm effective radius polycrstal phase function to the data. The model line is jagged because not enough photons have been used in the ray tracing calculations.

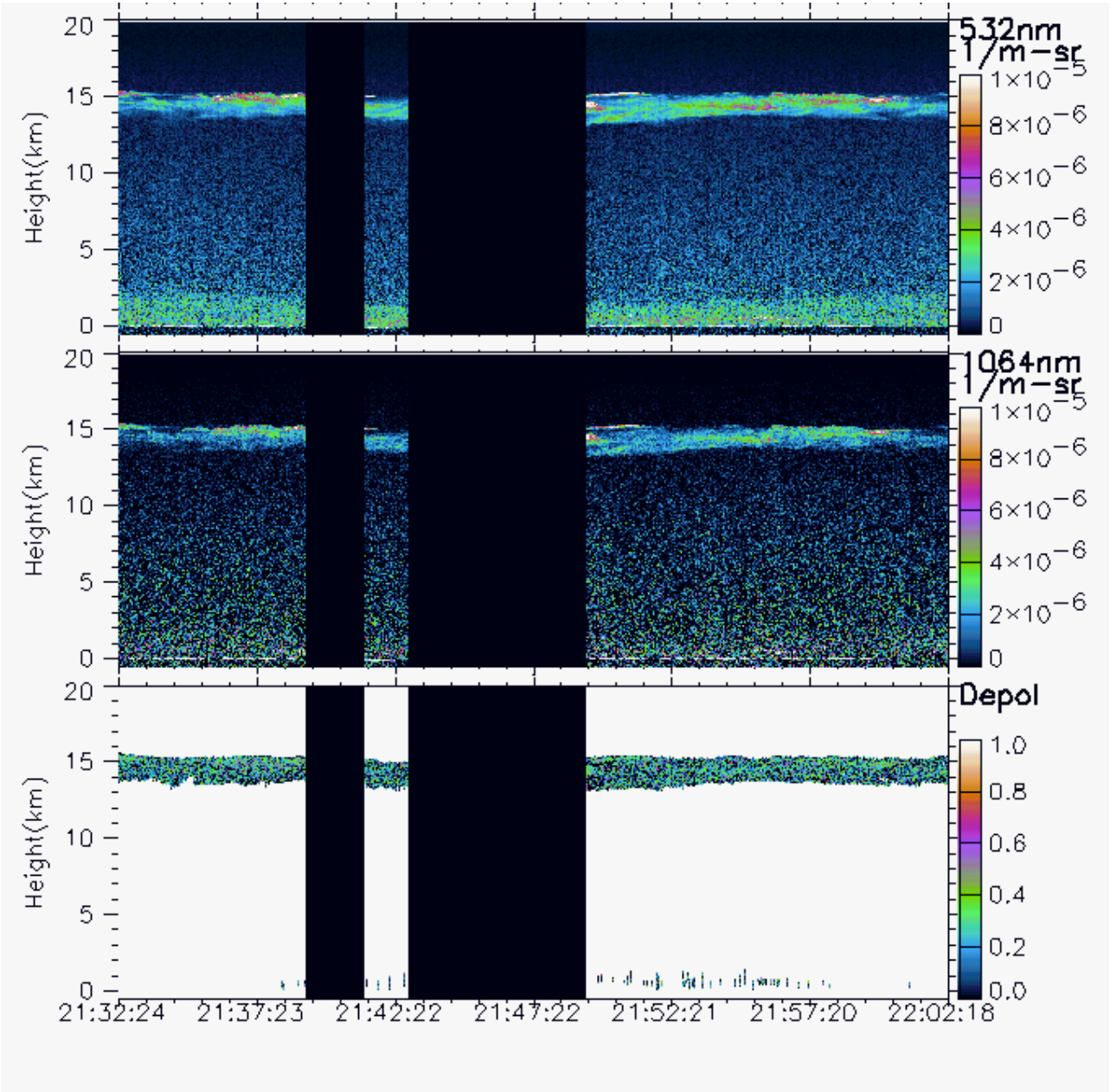




Very Thin Cirrus

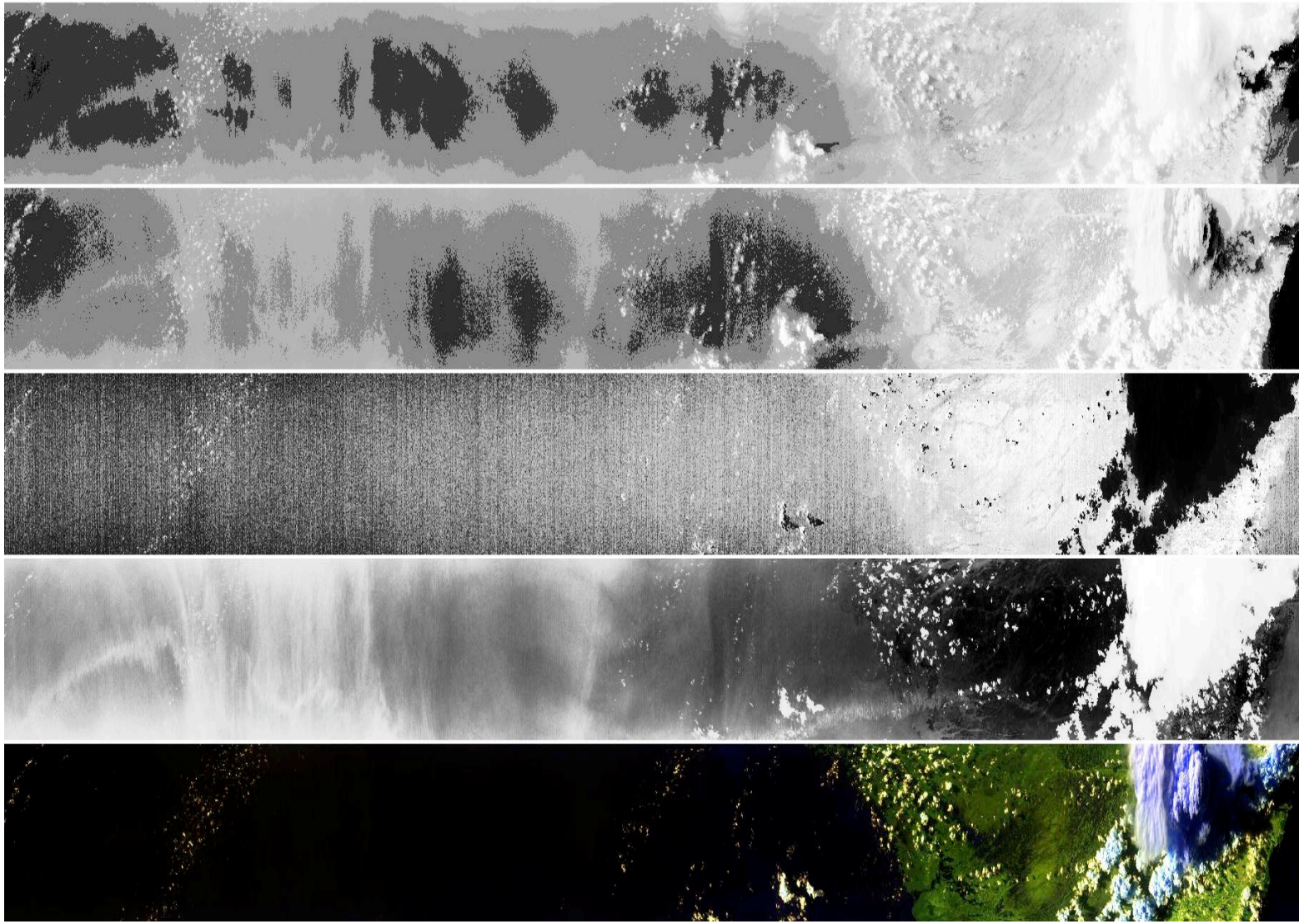
- Coincidence between ER-2, WB57 and Proteus was excellent at the end of the day on 07-13-2002.
  - Proteus is red, ER-2 blue and WB-57 green.



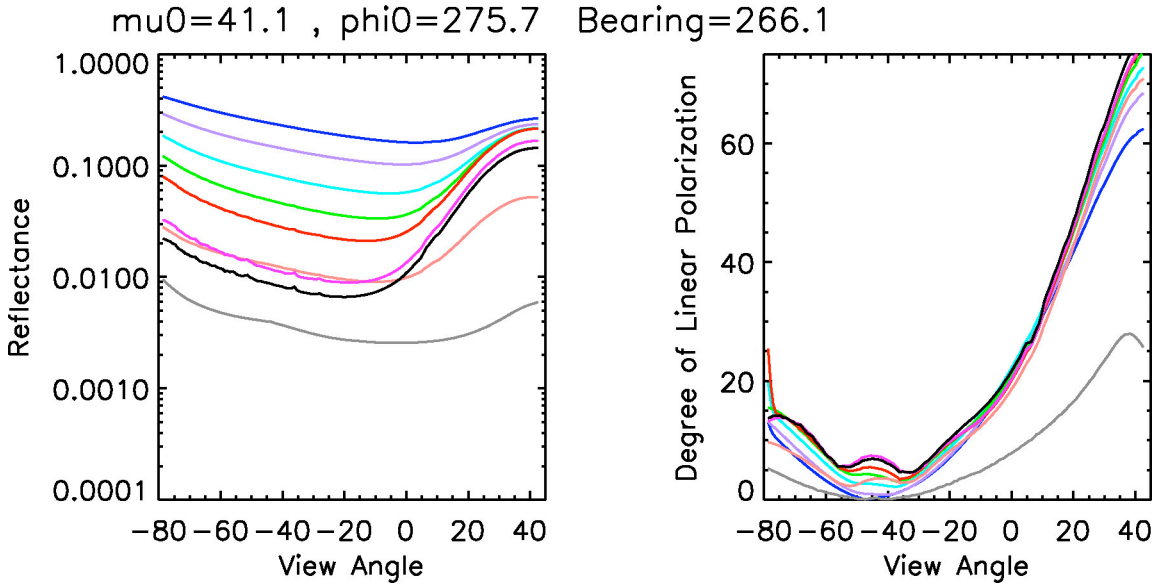


- This figure shows the Quick Look from the CPL on ER-2 for that day during the period of coincidence.
- This thin well defined layer extended from near the WGS to at least 20 km off shore

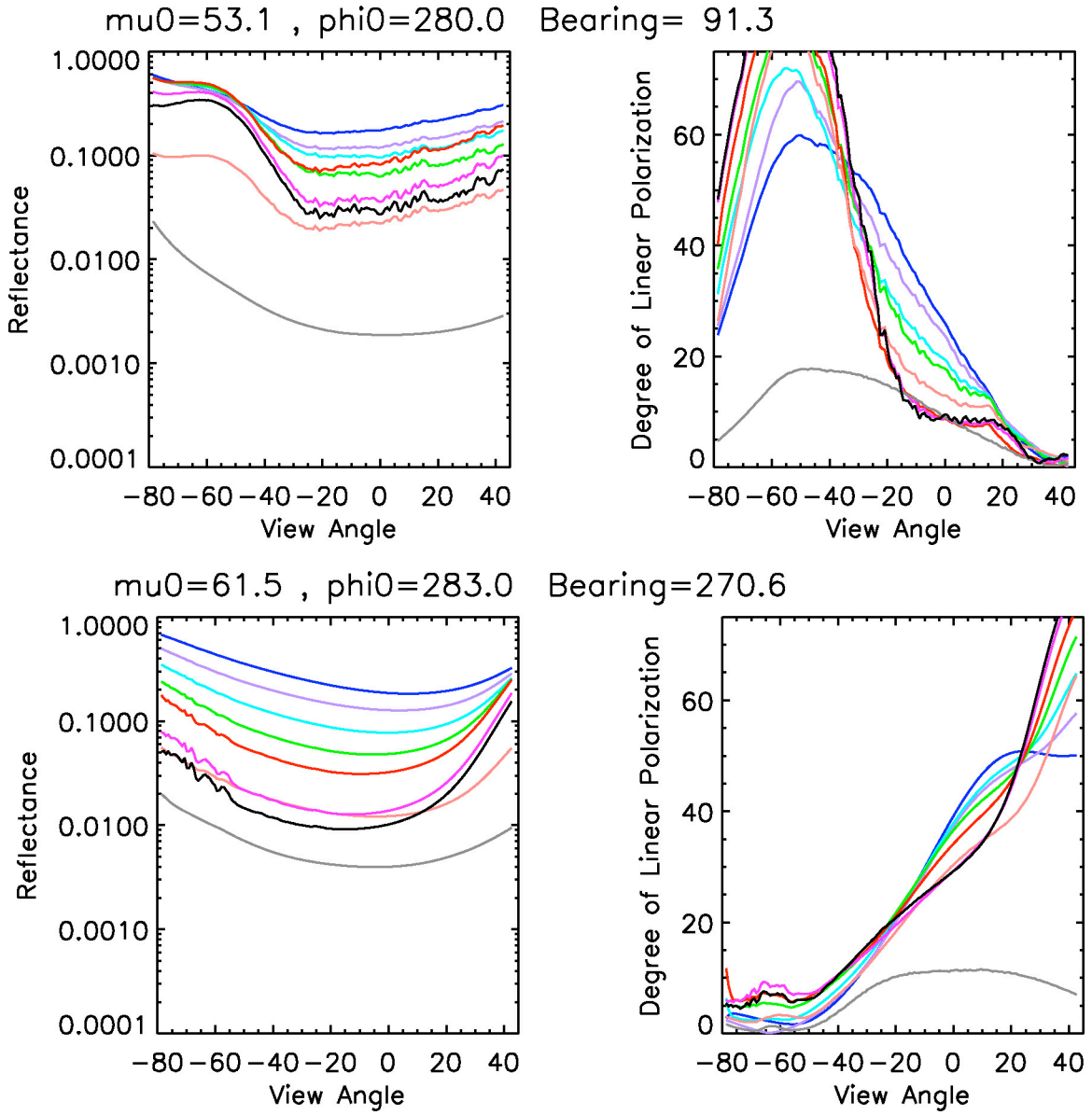
- MAS Quick Look showing increasing boundary layer cloud and then a convective event as shore is approached. This is flight line 013 on 07-13-2002.



- Over the open ocean the most obvious signal is
  - The aerosol/Rayleigh like spectral variation
  - The sunglint (+41° view angle)
  - Aerosol polarization signature near backscatter (-41° view angle)
  - Except for the 1880 nm band (grey) which has very low reflectance and also very low polarization.
  - When taken in conjunction with the location of the cirrus layer provided by CPL this indicates that the layer is very optically thin.



- Orientation of the flight track was almost ideal.



- The cirrus layer appears to be quite stable and these flight tracks are close to the solar principal plane
  - We see the polarization of the sun glint increasing as the sun drops lower in the sky
  - The peak polarization of the light scattered from the cirrus layer is decreasing with decreasing solar zenith angle, although there is no obvious increase in reflectance as one might expect.

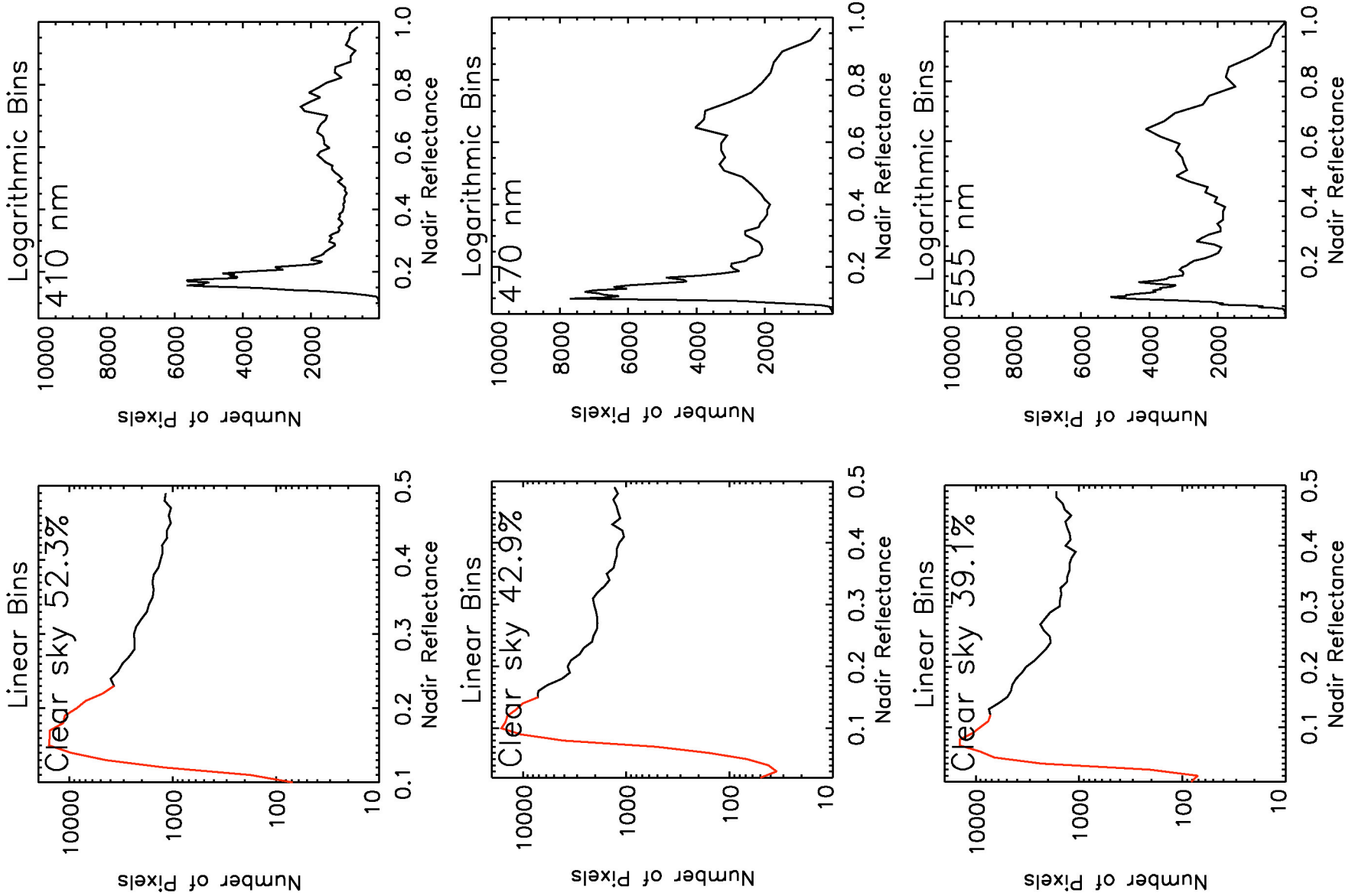
- We're currently doing more detailed analyses of this data using the NAST-I water vapor profiles and constraining the cirrus to lie in a layer defined by the CPL data to see if a single constant layer fits all of the data.

- This layer is also thin enough that we can retrieve the aerosol properties below it.

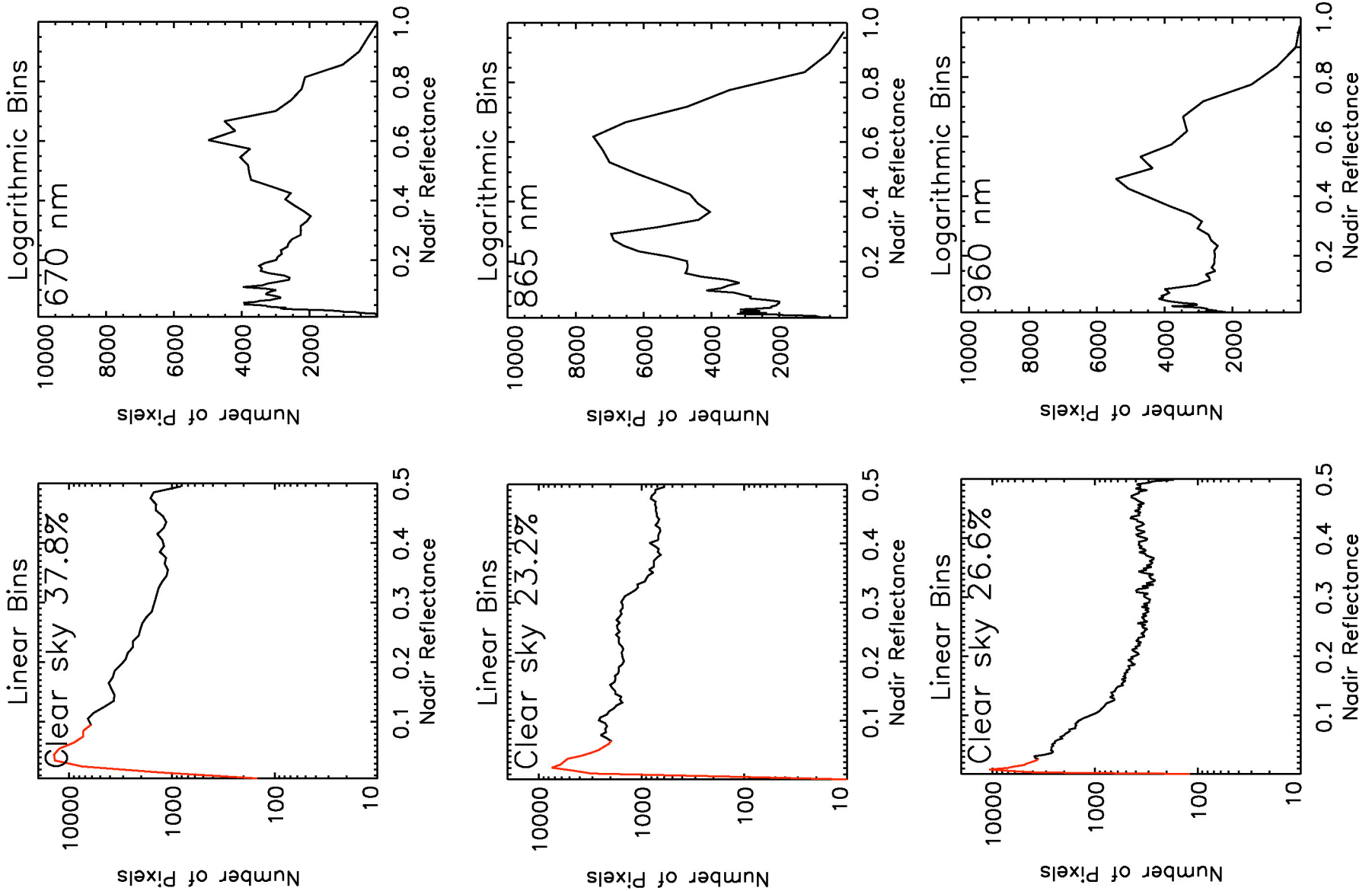
Reflectance Distributions

- The histograms below indicate the range of conditions observed during CRYSTAL
- The “clear sky” percentage is nominal and simply indicates the fraction of low reflectance scenes. These are not the thresholds used for cloud/clear identification.
- Land and ocean has not been separated.
- Polarization at 410 nm relative to a calculated Rayleigh scene (not shown) is an excellent cloud identification tool, since the variation in albedo between land and ocean/lakes is very small.

Reflectance Distributions



Reflectance Distributions



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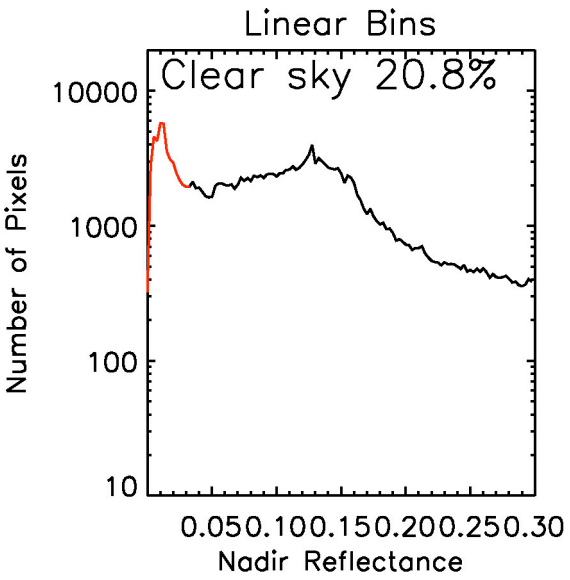

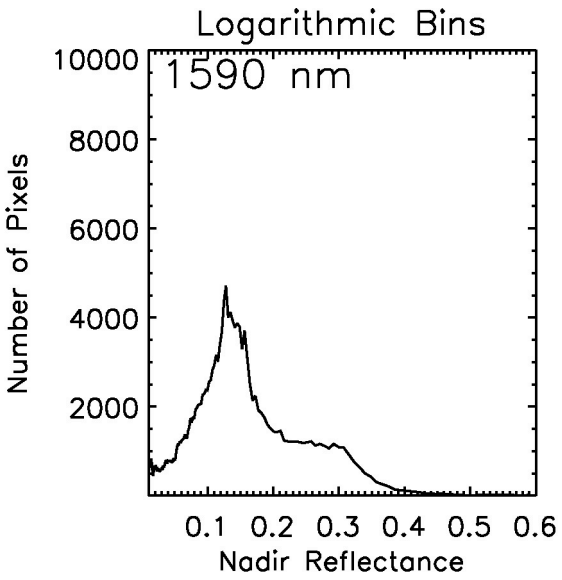

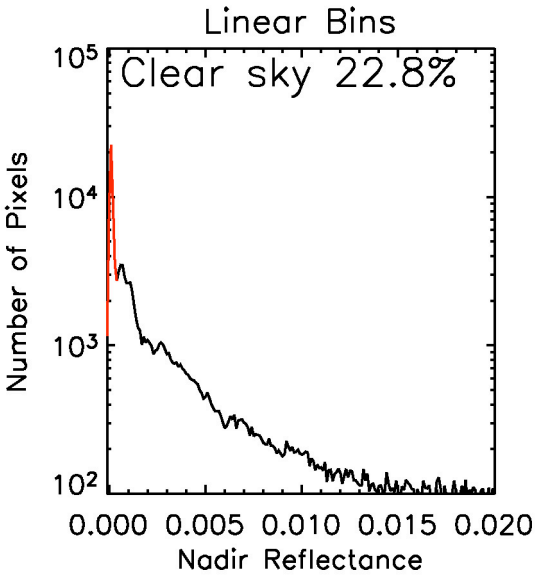

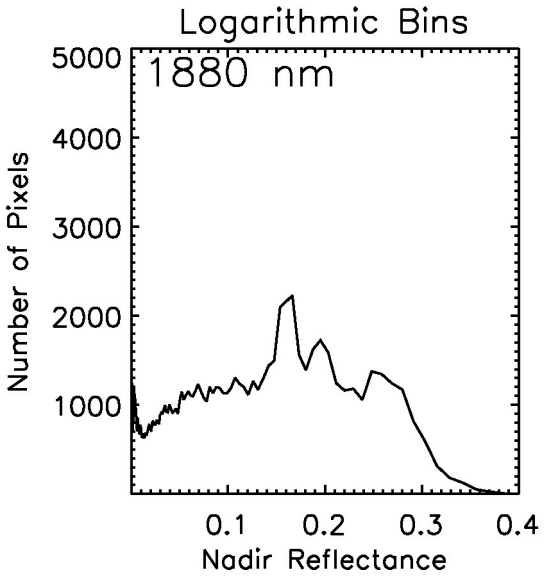

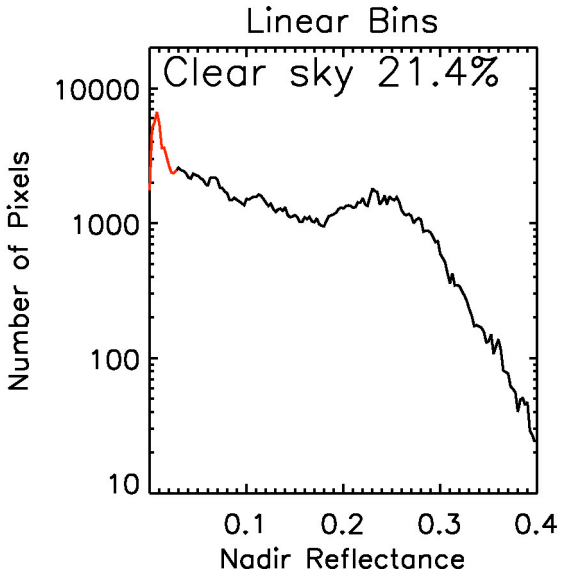

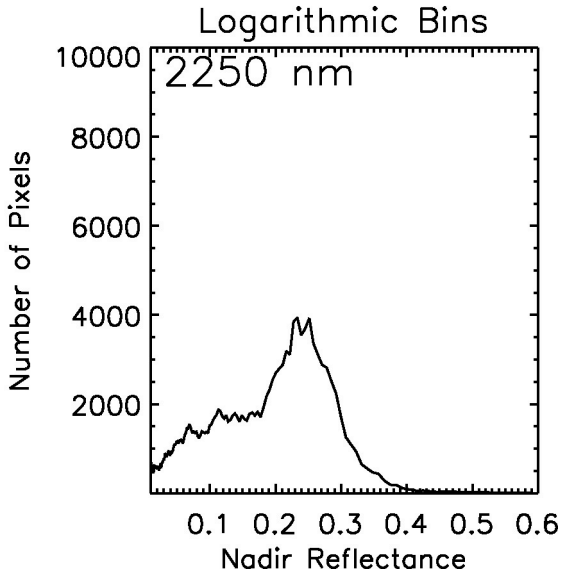

Summary

- There are numerous excellent coincidences between Proteus and both WB-57 and ER-2 throughout the campaign with both thick and thin cirrus present.
- There is also a significant amount of good cirrus data over the WGS with more limited samples over the EGS.
- The data is available, but will be revised and reformatted to make it more user friendly shortly (within two weeks) of the STM.
- Unless there is overwhelming demand to use HDF4 the data will be archived using netCDF.

Acknowledgements: The Proteus crew for providing support and help in making things work, above and beyond the call of duty. The CPL, MAS, NAST-M and NAST-I groups for use of their data and the FIRSC group for use of their tools.